LENSING SURVEY OF THE MOST X-RAY LUMINOUS GALAXY CLUSTERS

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We present the first three galaxy clusters of a larger sample of the most X-ray luminous galaxy clusters selected from the ROSAT Bright Survey. This project, which is a systematic search for strong lensing, aims at arc statistics, mass determinations and studies of distant lensed galaxies.
The three galaxy clusters presented here have been observed with the Wide Field Imager at the ESO2.2m in the R- and V-band. The images show lensing features like distinct distorted galaxies and arcs. Mass distributions of the lensing galaxy clusters and photometric properties of some arc candidates are presented. In addition we report the discovery of three giant arcs.

1 The Project

The project is based on a well defined sample of 21 intermediate redshift ($0.10 < z < 0.52$) galaxy clusters. These clusters are the most X-ray luminous systems taken from the ROSAT Bright Survey (Schwope et al.[9]). As the X-ray luminosity of clusters is well correlated with their mass (Reiprich et al.[6], Schindler,[7]) this sample is assumed to consist of very massive systems and hence the probability for them to act as gravitational lenses is very high.
The goal of the project is a search for gravitational lensed objects, mainly arcs. These objects are highly magnified images of very distant galaxies and hence they are useful probes for galaxy formation and their evolution. In addition they can be used for investigations on the mass distribution and mass estimates of their lensing clusters (see Bartelmann&Schneider,[2] for a review on gravitational lensing). Finally, the frequency of giant arcs is a powerful tool to constrain and distinguish cosmological models (Bartelmann et al.[1], Wambsganss et al. [10]).
The observations were done with the SUperb Seeing Imager2 (SUSI2@ESONTT) and the Wide Field Imager (WFI@ESO2.2m) in La Silla between August 2001 and April 2004. All clusters are observed in the R- and V-band, with the exposure time in R usually being about twice that in V.
The data reduction is perfomed with the GaBoDS pipeline (Schirmer et al.[8], Erben et al.[4]). This pipeline provides the data reduction in several steps: basic reduction (bias correction, overscan correction, normal flatfielding), superflatting/defringing, astrometric and photometric

property	RBS325	RBS653	RBS864
z	0.282	0.286	0.2906
L_x [erg/sec]	44.8	44.9	45.3
FWHM$_{stars}$ (R#813) [arcsec]	0.95	1.30	1.15
FWHM$_{stars}$ (V#812) [arcsec]	1.1	1.05	1.25
TOTAL # of detected galaxies	1567	1285	1138
limiting R-magnitude ($> 3.0\sigma$)	25	25	25
limiting V-magnitude ($> 3.0\sigma$)	25	24.5	25
# of USED galaxies (see sec. 3)	1083	1035	873

Table 1: summary of the cluster properties, $L_x = \log$(X-ray flux).

calibration and, finally, a coaddition is performed.

2 WFI observations

In this proceedings contribution we present the first three clusters RBS325, RBS653 and RBS864. All observations were done at good seeing conditions (≤ 1") with the Wide Field Imager during April 2002. In total there are 30 R-band images (ESO filter BB#Rc/162_ESO844) with an exposure time t_{exp} ∼4.46h of the coadded image, and 15 V-band images (BB#V/89_ESO843, t_{exp} ∼2.23h) per cluster, except RBS653 where we have obtained only 15 R-band images due to bad weather conditions (t_{exp} ∼2.23h in both R and V). The limiting magnitudes above a 3σ detection threshold are given in Tab.1.

3 Galaxy/Cluster Detection

The galaxy detection was performed with SExtractor 2.3.2 and a 3σ detection limit. From the extracted catalogue we selected all objects with the following properties: (a) objects within a Field of View (FOV) of 1500×1500 pixels ($\sim 6' \times 6'$) centered on the cluster position given in the ROSAT Bright Survey, (b) FWHM$_{object}$ > FWHM$_{stars}$, derived from R$_{mag}$ vs. FWHM plots, and (c) CLASS_STAR parameter of SExtractor ≤ 0.85, so we only select objects SExtractor assumed to be galaxies.
Tab. 1 shows the properties of the three galaxy clusters and the constraints on the selected objects. The resulting catalogues were used to extract the members of the foreground lensing cluster (the Red Sequence). The galaxy number density plots (Fig. 1) were obtained by creating blank images of the same size as the chosen Field of View ($\sim 6' \times 6'$, 1500×1500 pixels) and allocating pixel value "1" to all positions referring to Red Sequence galaxies. This image is then strongly smoothed with a $\sigma = 300$ pixel Gaussian.

4 Preliminary Results

4.1 Galaxy Number Density Plots

Fig. 1 presents the galaxy clusters RBS325, RBS653, and RBS864, the contours represent the galaxy number densities of the corresponding Red Sequence.
RBS325 looks like a cluster which is at the start of a merging process: there is a significant alignment towards the north-east direction in the number density plot, which could indicate the direction of a starting infall. In contrast to that RBS653 shows no main direction in the galaxy number density plot. However, lots of substructures can be seen, which indicates an advanced ongoing merger. The galaxy number density plot of RBS864 presents only marginal

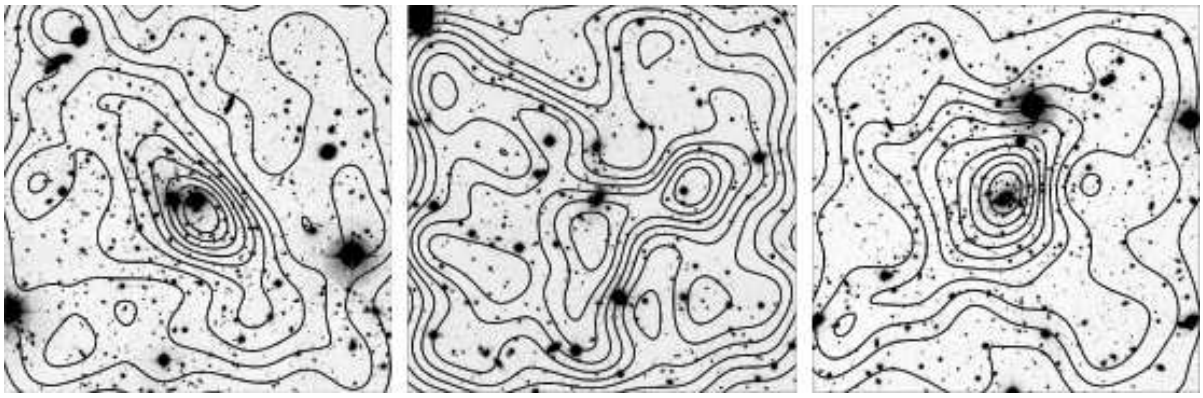

Figure 1: R-band images of RBS325 (left), RBS653 (middle) and RBS864 (right). The Field of View is $6' \times 6'$ in all images ($\sim$ 2Mpc $\times$2 Mpc), north is up, east to the left. The contours show the galaxy number densities of the Red Sequence (see text for more details).

RBS325	A1	A2	A3	A4	A5	A6	A7	B1	B2	B3
(V-R)	0.15	0.12	0.14	0.15	0.15	0.13	0.06	1.61	1.08	1.27
R mag	21.6	24.0	24.8	22.3	24.0	23.2	22.7	22.8	24.8	23.3
RBS653	C1	C2	C3	C4	C5	C6	C7	-	-	-
(V-R)	0.23	0.33	0.28	0.15	0.22	0.27	0.13	-	-	-
R mag	23.5	22.9	22.2	23.2	21.0	23.1	23.5	-	-	-

Table 2: Photometric properties of the objects marked in Fig. 2

substructures. This has been expected as a massive cooling flow is known for this cluster (Edge et al.[3]).

4.2 Photometry, Colours and Lensing Effects

As all our galaxy clusters are assumed to be very massive systems the probability for them to act as gravitational lens is very high. Extrapolating from the EMSS numbers for galaxy clusters in different X-ray luminosity ranges (Luppino et. al.[5]) we expect to find arc(lets) in 45% of our clusters. RBS864 shows no obvious strong lensing features, so we focus here on RBS325 and RBS653.

Fig. 2 left shows the centers of the clusters RBS325 and RBS653, the right part shows the (V-R) vs. R-magnitude diagram with the Red Sequence galaxies between the two lines. The most interesting objects are marked in both, their photometric properties are listed in Tab. 2. It can be seen that the objects marked with "A" in RBS325 nearly have the same color. In addition, A1, A5 and A6 show a tangential alignment with respect to the cluster center. So the possibility that these are lensed background objects is very high and will be checked by forthcoming observations. Objects B1, B2 and B3 are very red and possibly highly magnified very distant objects.

Also RBS653 shows several objects (marked with "C") with a different color index than the Red Sequence (compare Tab. 2). In addition we report the discovery of several giant arcs, denoted by "D". The distances from the cluster center are roughly $\sim$21" ($\sim$37 kpc, assuming $H_0 = 72 kms^{-1}Mpc^{-1}$), $\sim$10" ($\sim$18 kpc) and $\sim$20" ($\sim$35kpc), their lengths are $\sim$16" ($\sim$28kpc), $\sim$7" ($\sim$12kpc) and $\sim$9" ($\sim$16kpc) for D1, D2, and D3, respectively.

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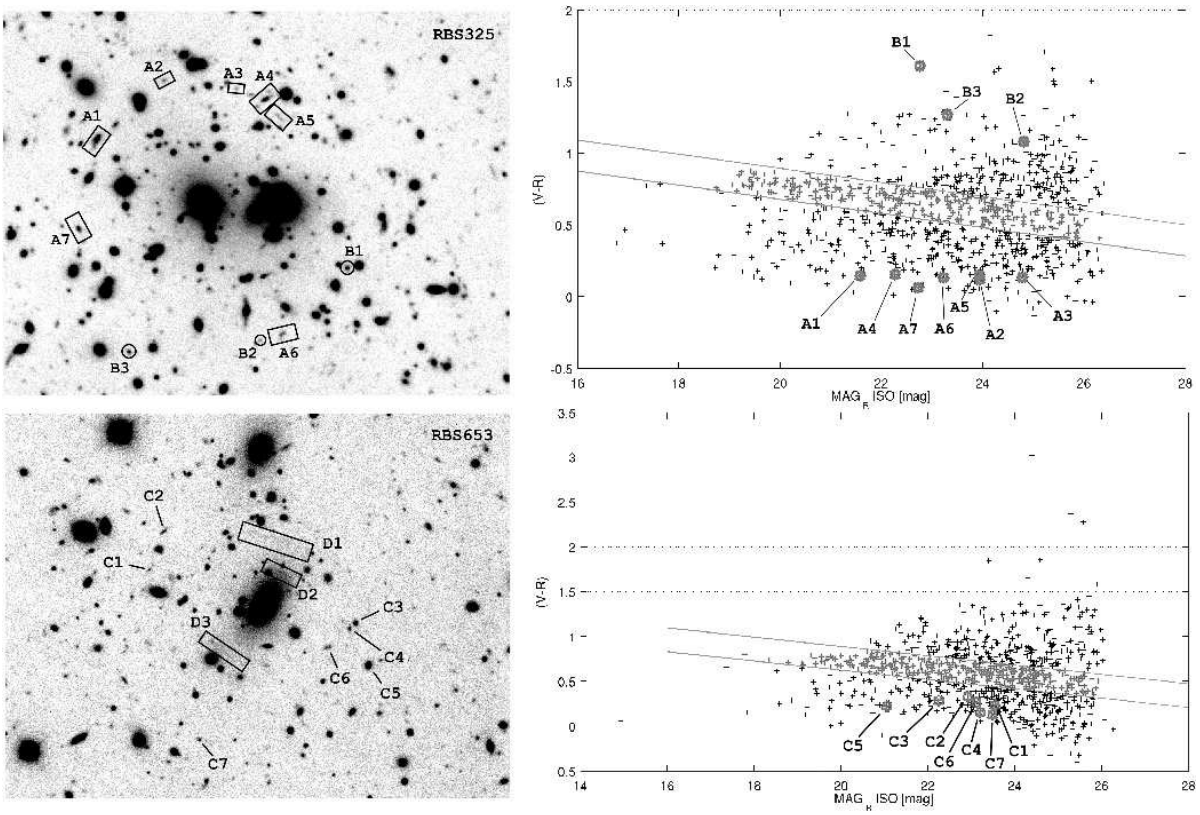

Figure 2: Left: center of the clusters RBS325 and RBS653 (FOV $\sim 2.5' \times 2'$). Right: color-magnitude plots for both clusters (see text for more details)

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